Boeing ATM Tools, Models and Simulations

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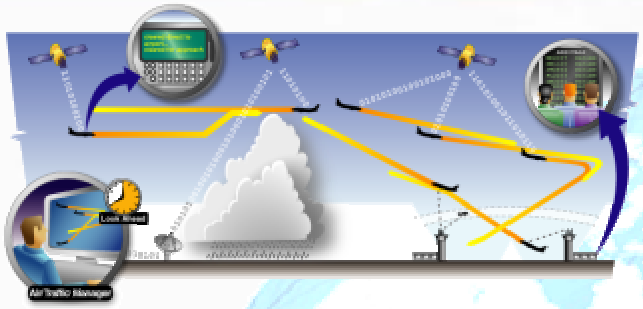
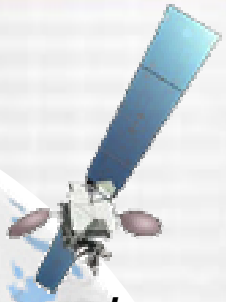
5/21/2003

Vision:
Revolutionary architecture

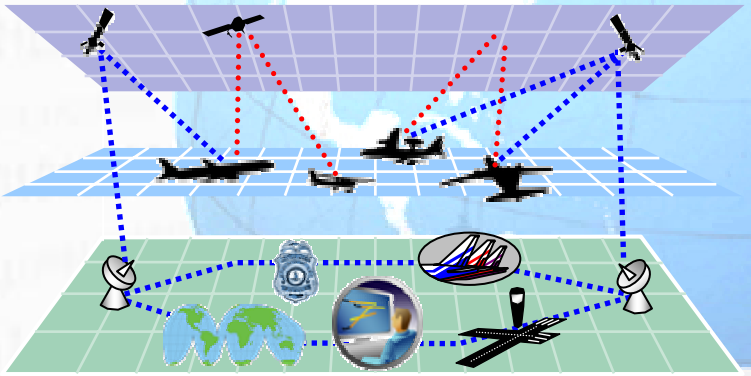


Trajectory-based airspace management

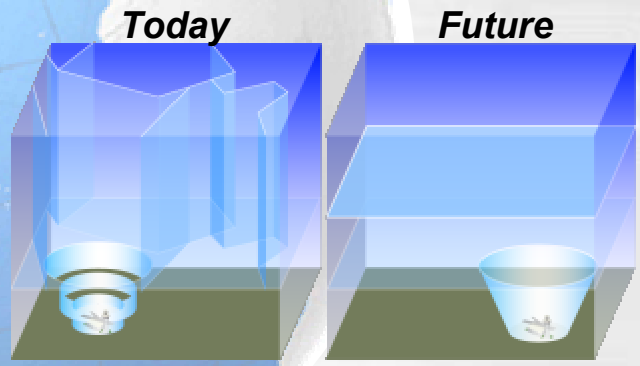


Satellite-enhanced communication, navigation, and surveillance

Integrated total system solution



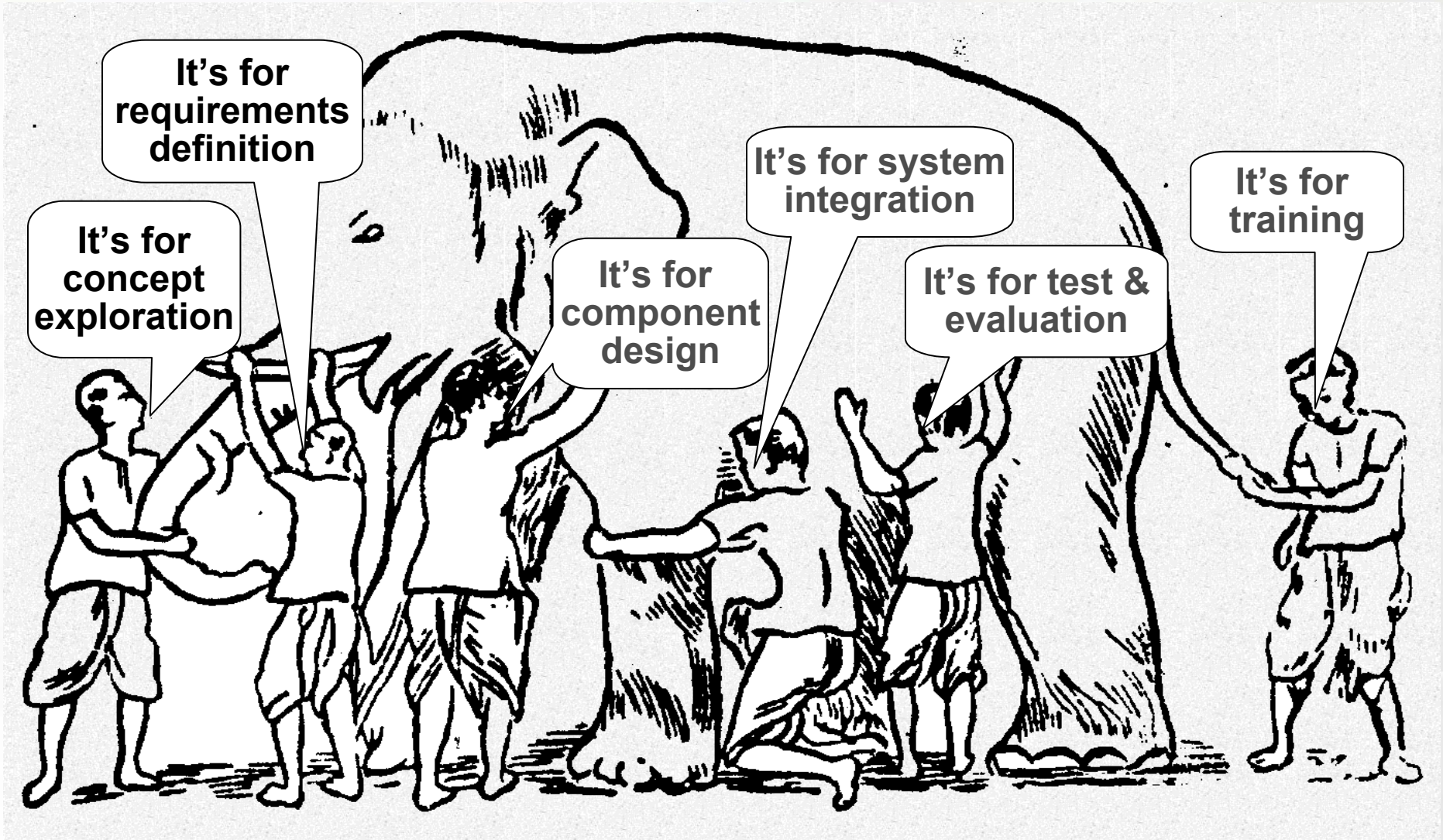
Common Information Network



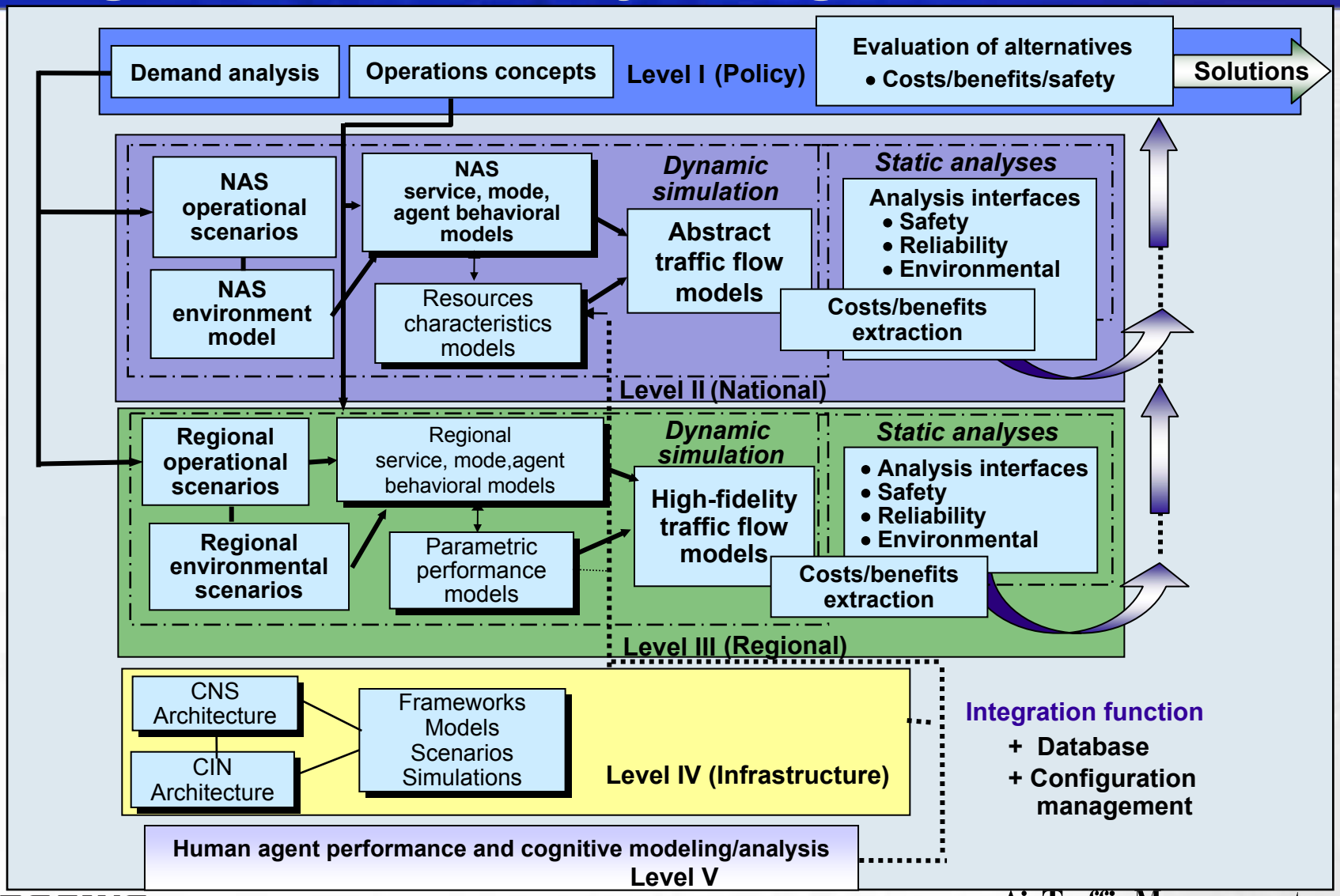
Simplified airspace design

- "Layered" security approach
- Open system principles—growth for the future
- Phased transition plan—builds on existing plans

What is modeling and simulation ?



Boeing ATM Preliminary Design Toolkit



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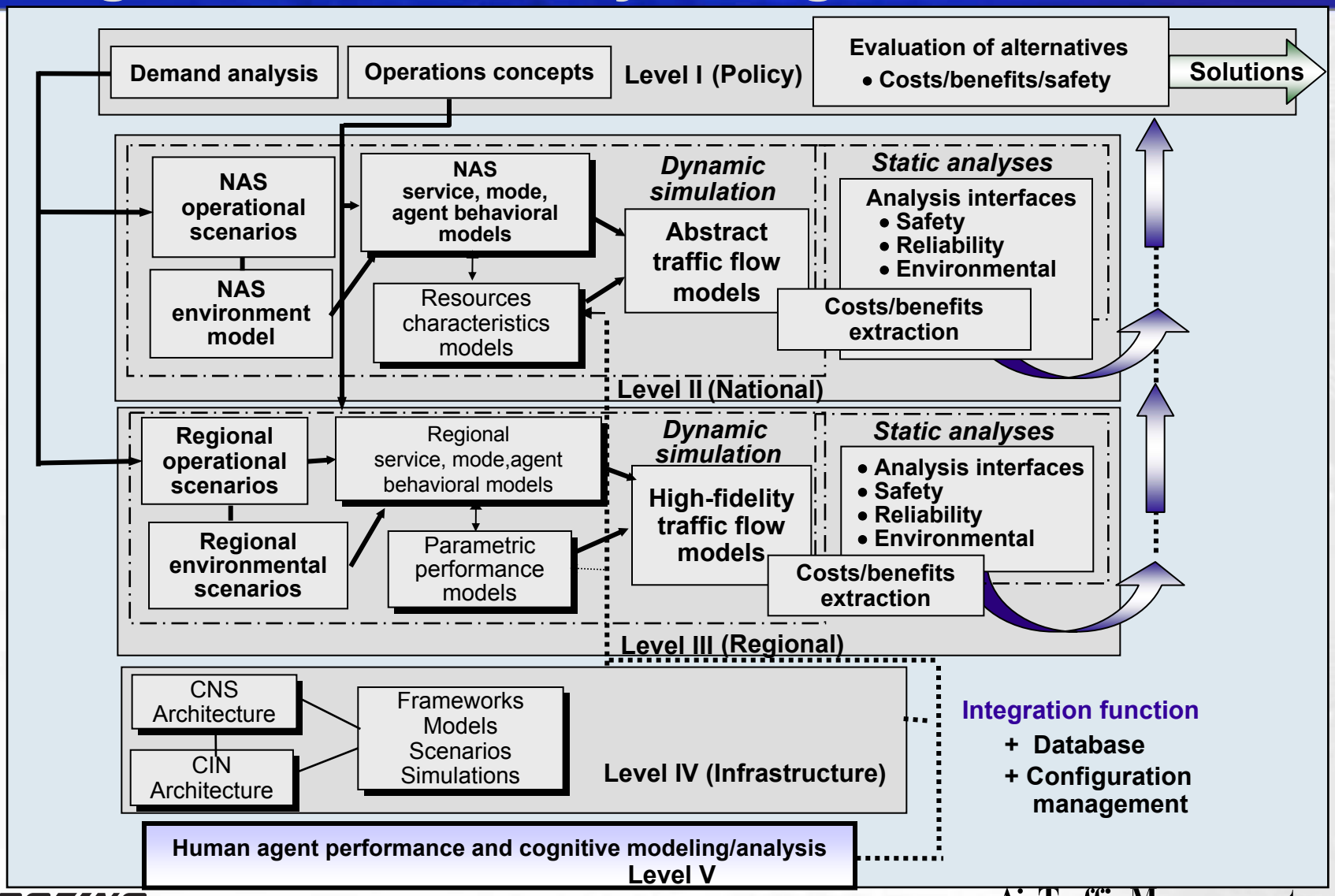


Model Human Processor

Card, Moran and Newell 1983

Model Human Processor Model

- The basic perspective is that people are information processing machines with regular (and determinable) processing characteristics
- The MHP is an intentionally simplified model of human performance, intended to provide gross predictions of system behavior
- The detailed properties of the human nervous system and perceptual organs provide important constraints and design possibilities for interaction

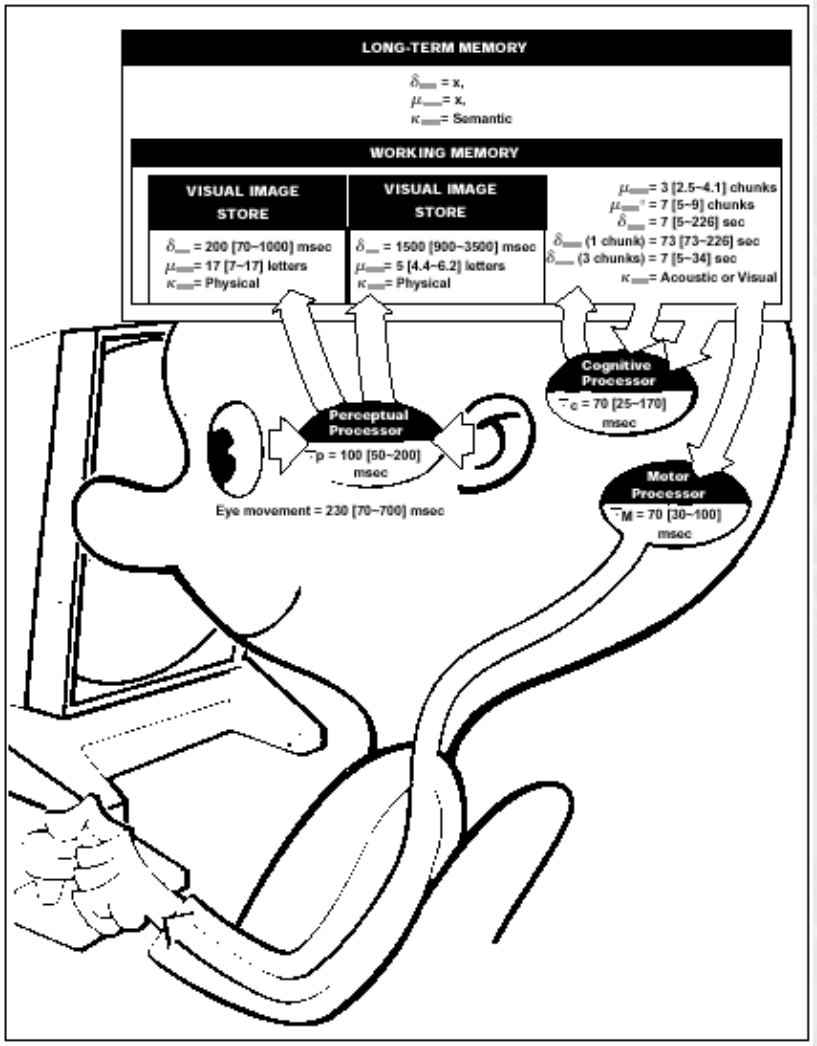
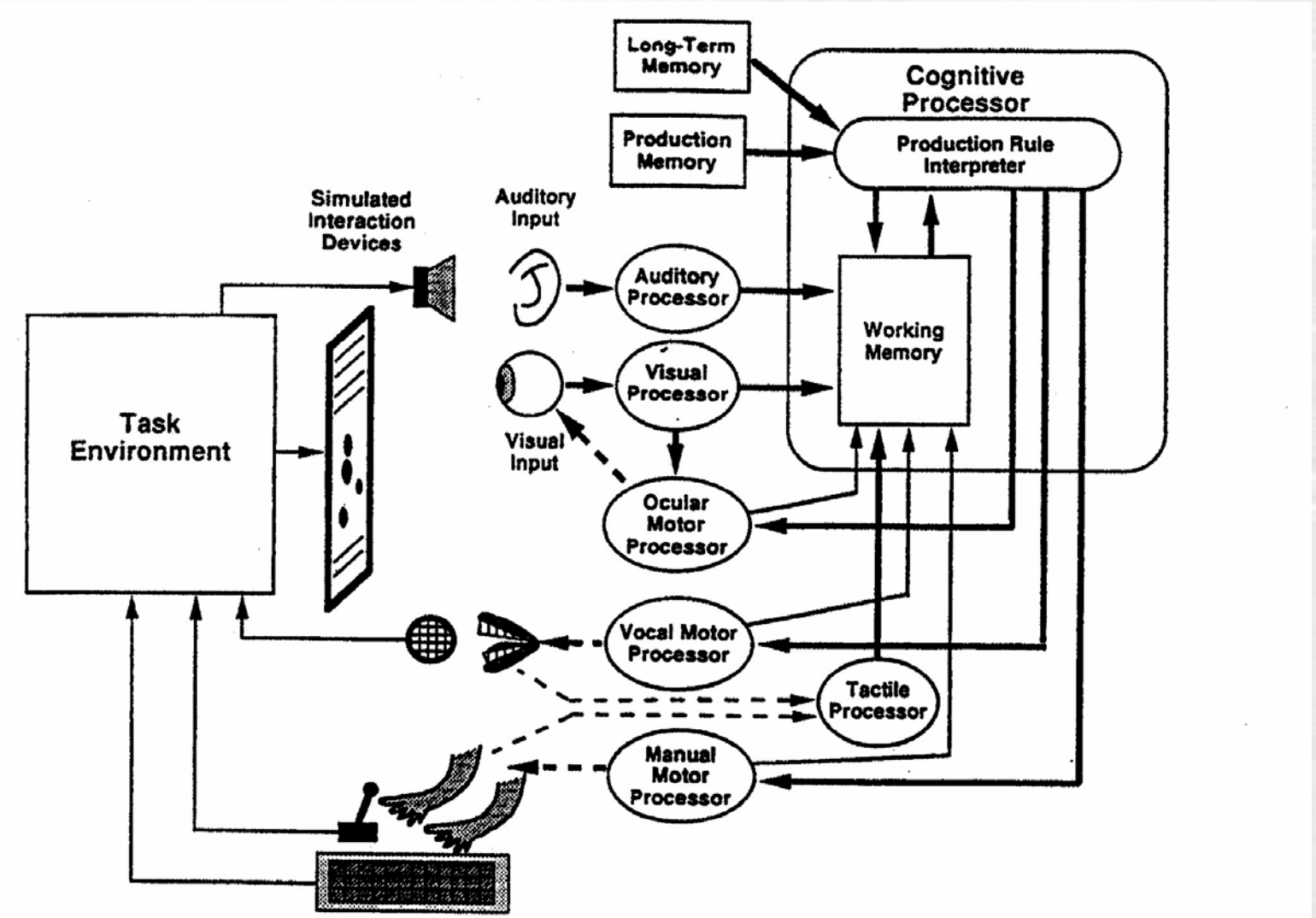


Diagram of the EPIC model



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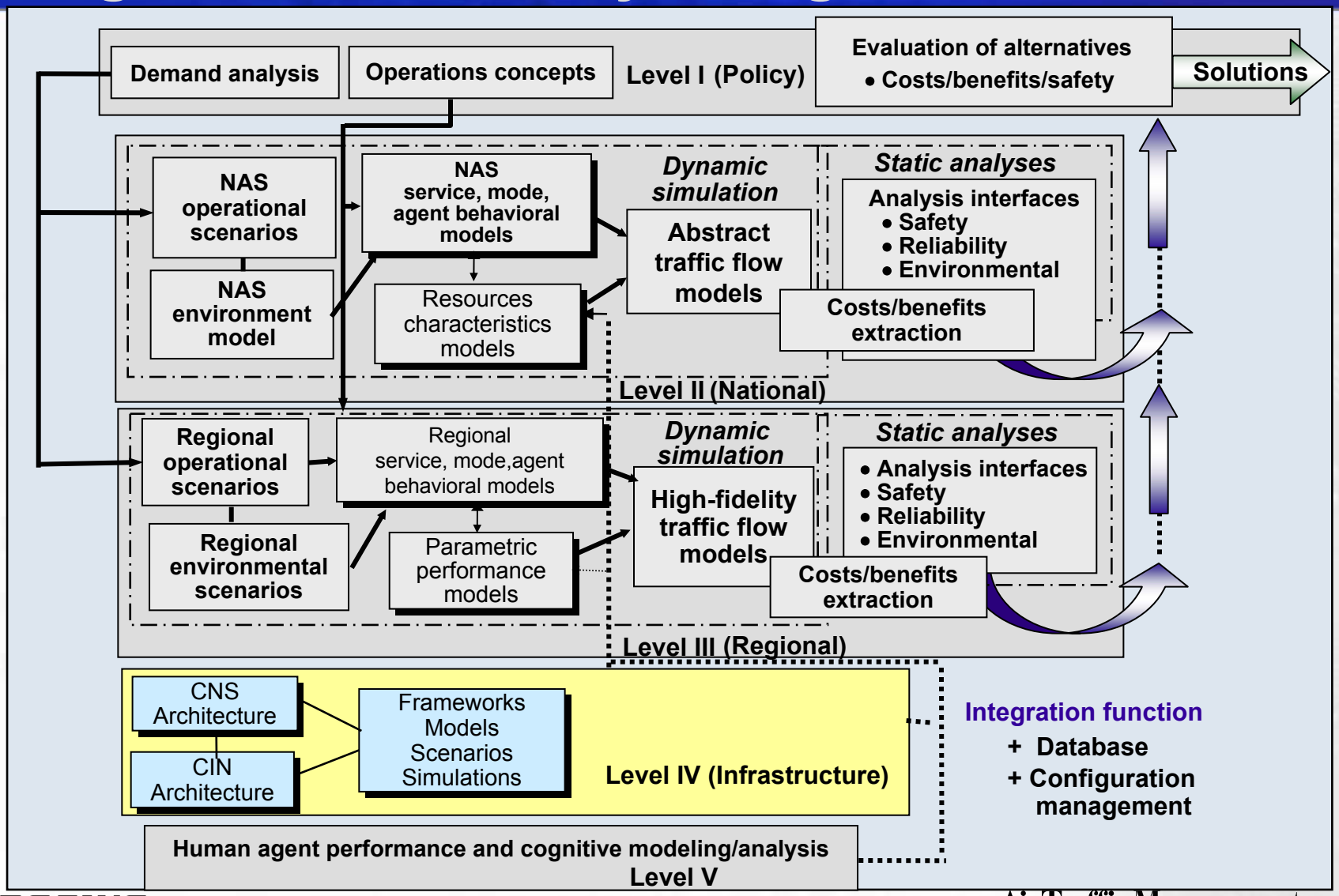
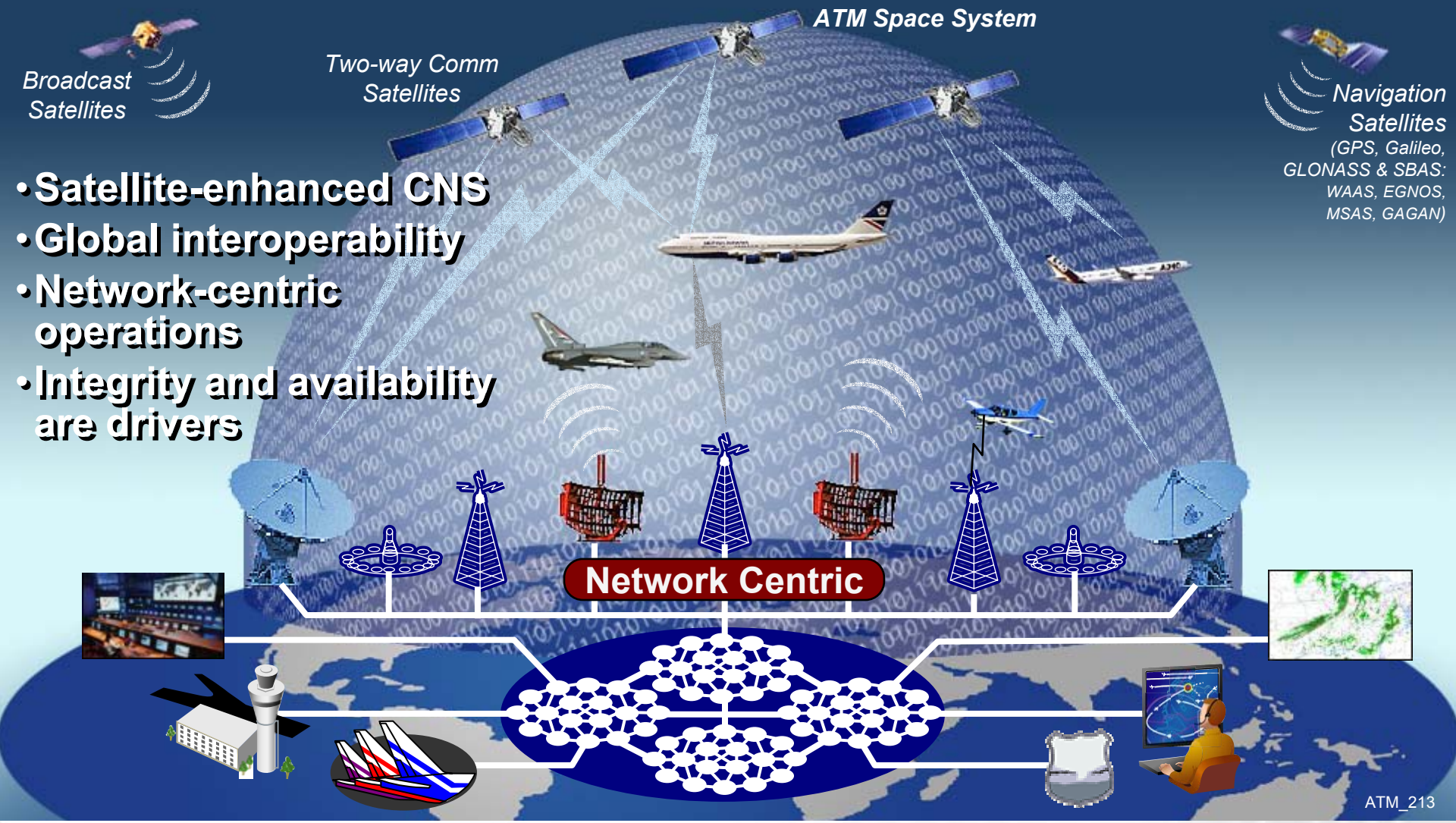
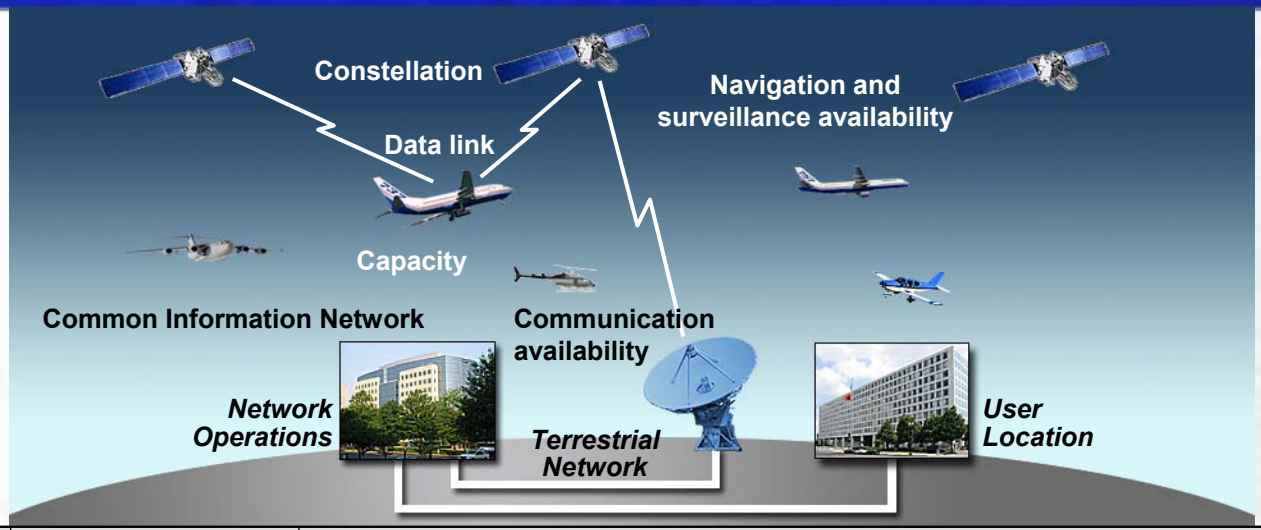


Global system-of-systems architecture



- Satellite-enhanced CNS
- Global interoperability
- Network-centric operations
- Integrity and availability are drivers

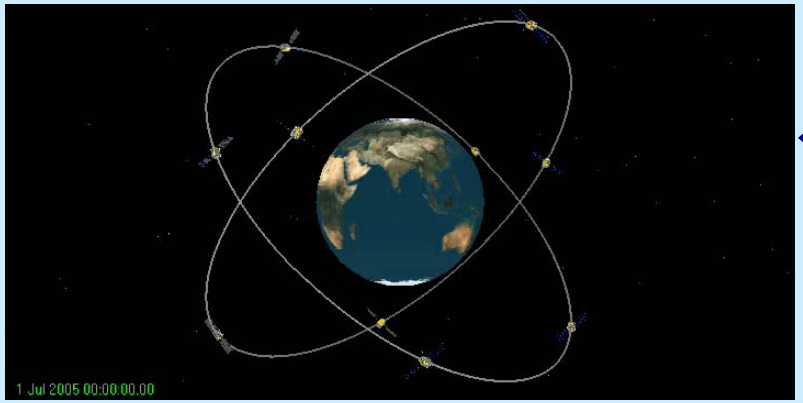
Architecture models



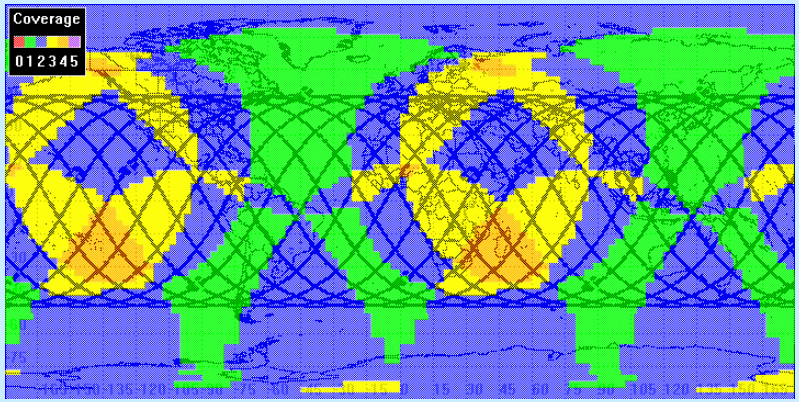
Coverage	Name	Detail
	Capacity Demand Model	Determines and represents the resource demands of current and new operational concepts on the system infrastructure and its components
	Data Link Simulation	Assesses the ability of the air-ground link communication infrastructure to satisfy the performance requirements of security applications and operational concepts
	Constellation Capacity Simulation	Uses the Capacity Demand Model and its inherent sensitivities to daily variation and geographic demand to determine the viability of existing space-based infrastructures and the appropriate sizing of future space-based architectures
	Constellation Latency Simulation	Establishes the ability of a space-based ATM infrastructure to meet necessary latency variation requirements
	Common Information Network Simulation	Measures the performance of network and information architectures in meeting ATC and security information exchange requirements
	Communication Availability Model	Determines the achievable availability, including factors such as architecture, capacity, demand, security threats, and atmospheric impacts within a specified spectrum
	Navigation and Surveillance Availability Model	Establishes the availability at various levels of accuracy for navigation and surveillance services, using factors such as spacecraft quantity, geometry, redundancy, user equivalent range error, and security threat

System-of-systems modeling

STK

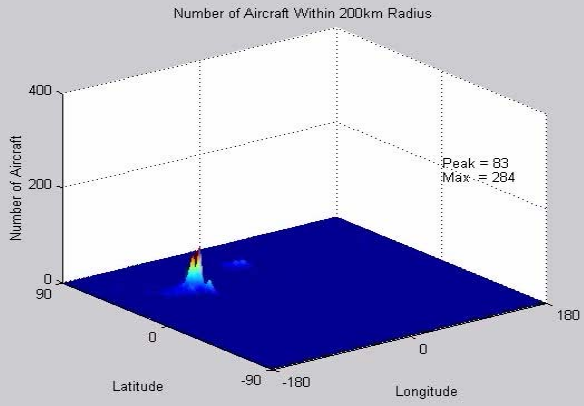


Orbit Visualization

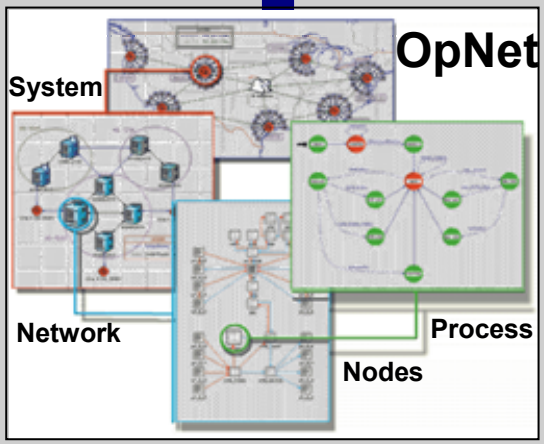


Instantaneous Coverage

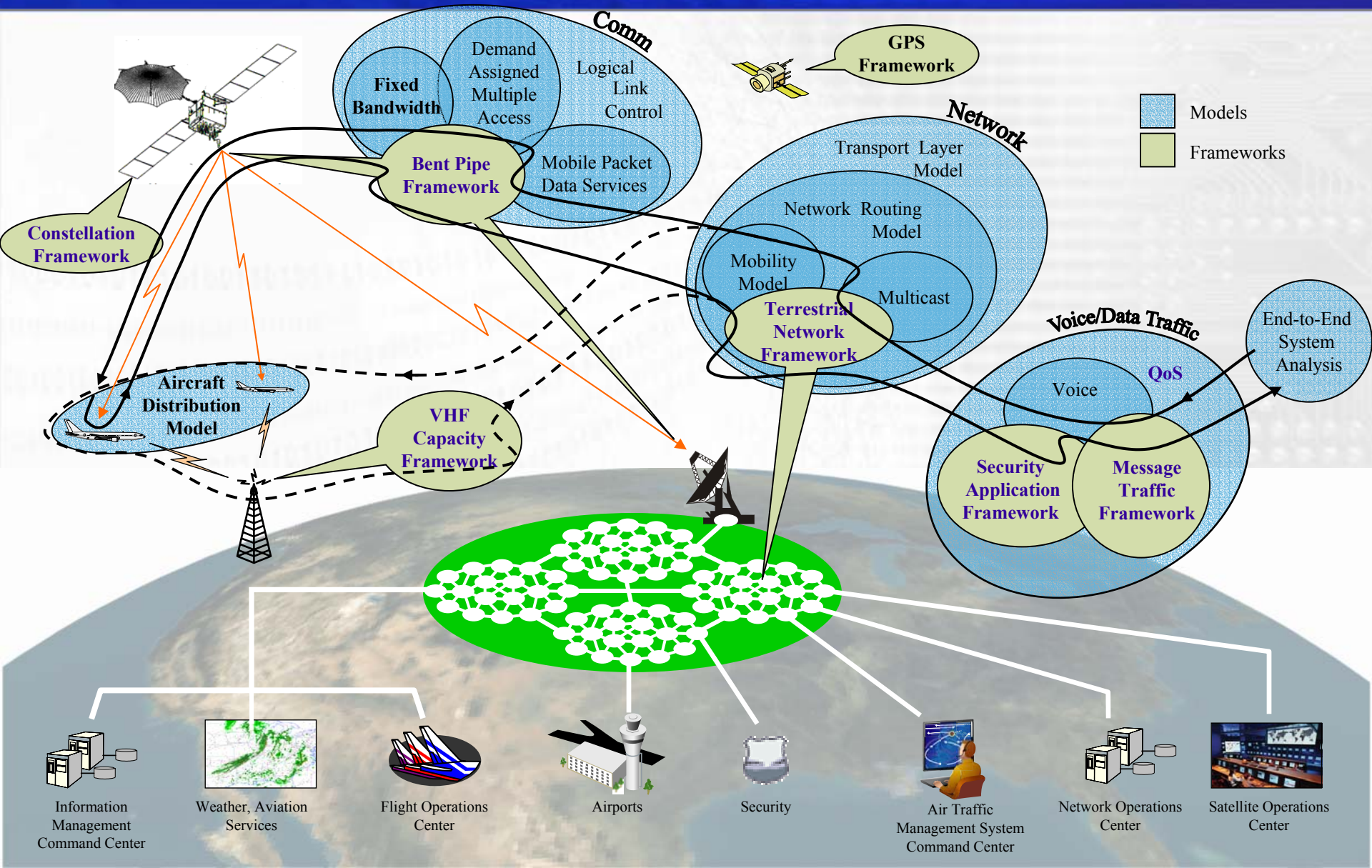
Matlab



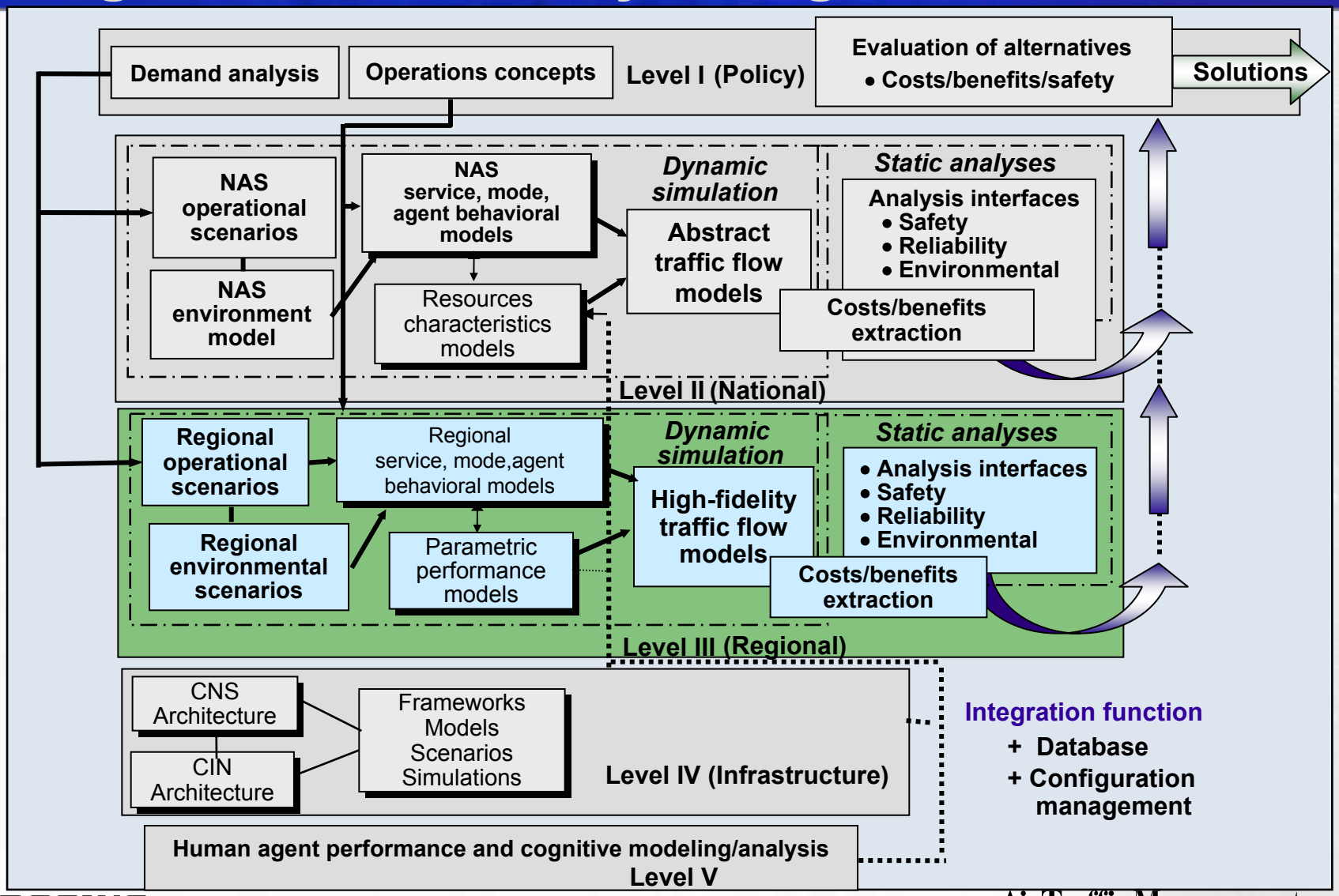
Instantaneous Traffic Density



CIN-CNS frameworks & models

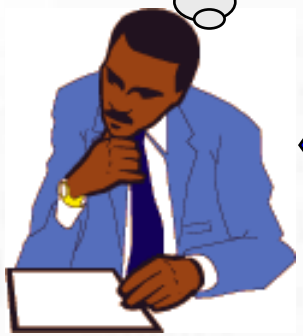


Boeing ATM Preliminary Design Toolkit



DESIDE concept
(Discrete-Event Simulation Interactive Development Environment)

Preliminary design process is a performance-based modeling approach
- Most S/W tools analyze a pa set of the technology
- We will develop models to m parameters and they will be drive technology developr an "honest broker" in trades



Domain Analyst
Object-Oriented (OO) / Universal Modeling Language (UML) trained

DESIDE Fr

- Library of model classes
- Graphic UML interface
- Reduced dependency on code to capture model

Model Creation

- Product = C++
- Runtime architecture
- Dynamic instances
- External attributes

Auto-generated code

Post Processing Tool(s)

Simulation Execution DES Engine

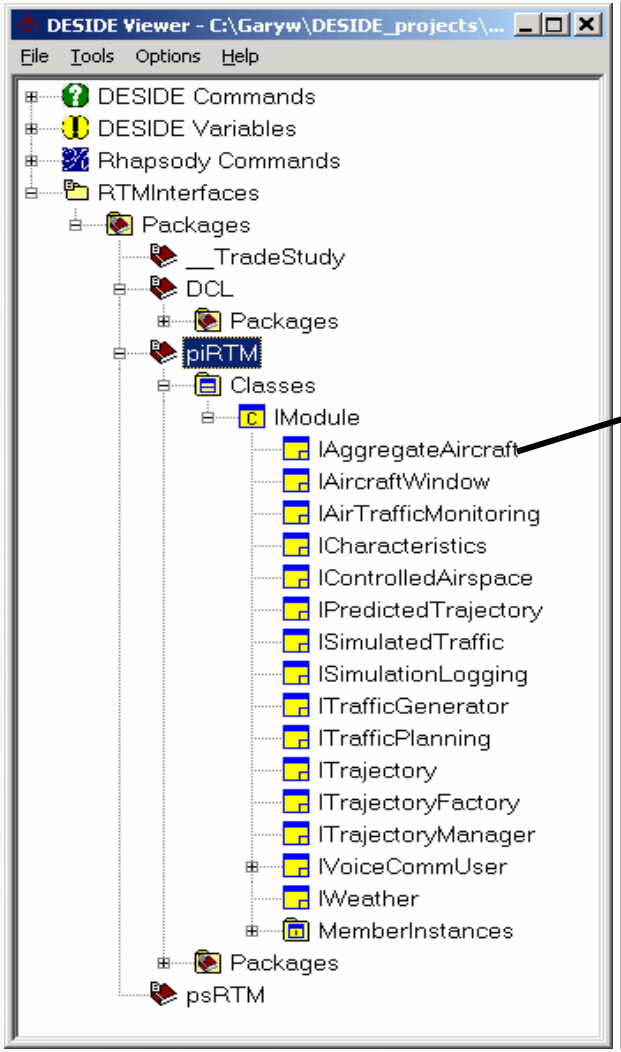
- Has both single & multi CPU– easily mapped into parallel processing platform
- Preserves causality

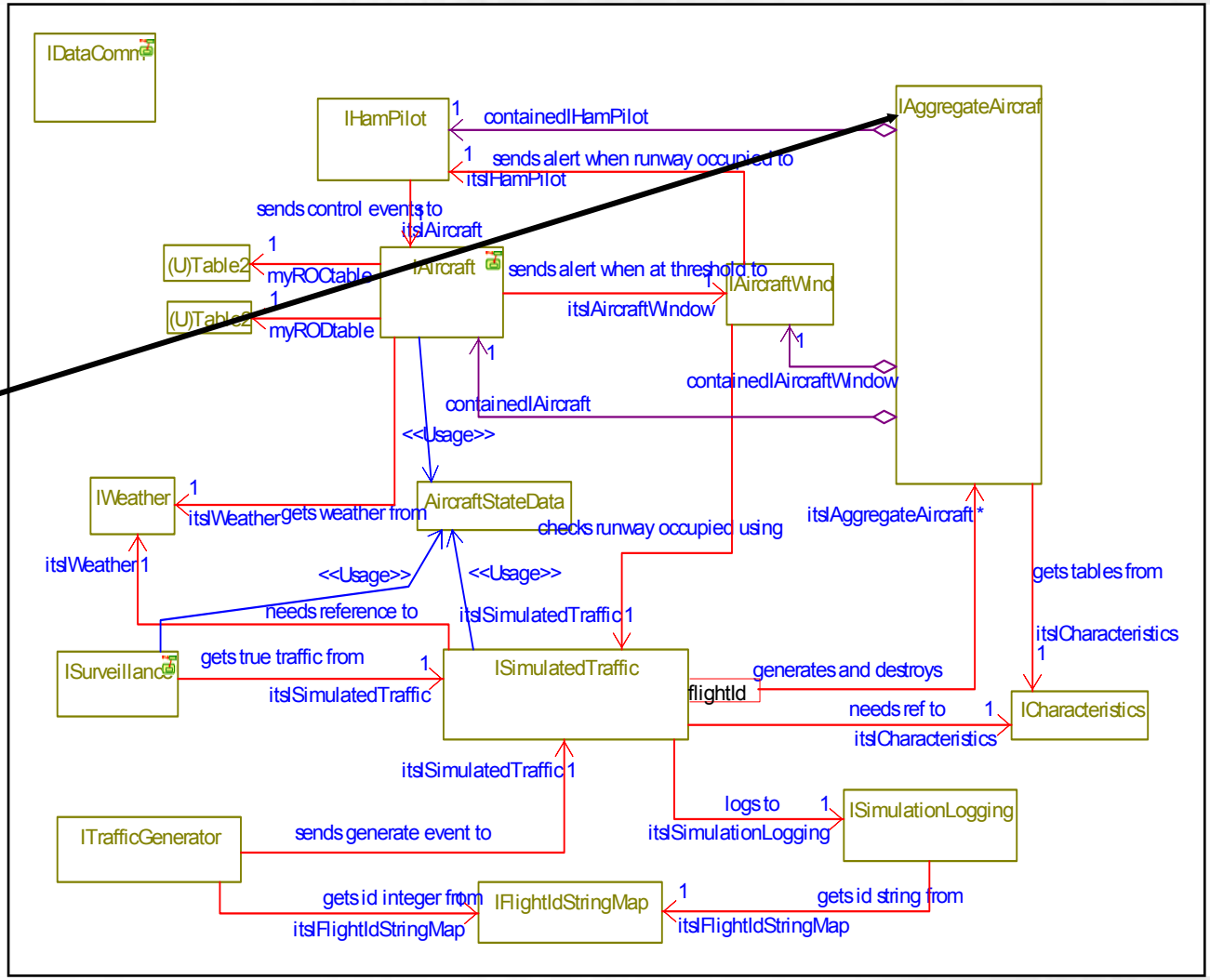
Results

Data Presentation & Visualization Tool(s)

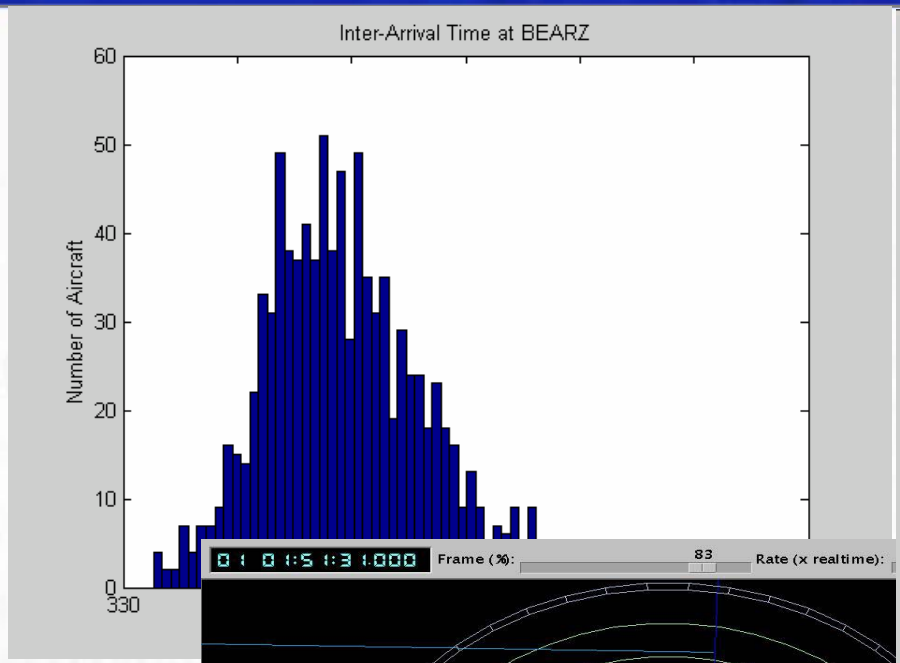
DESIDE facilitates direct access to simulation modeling by domain experts

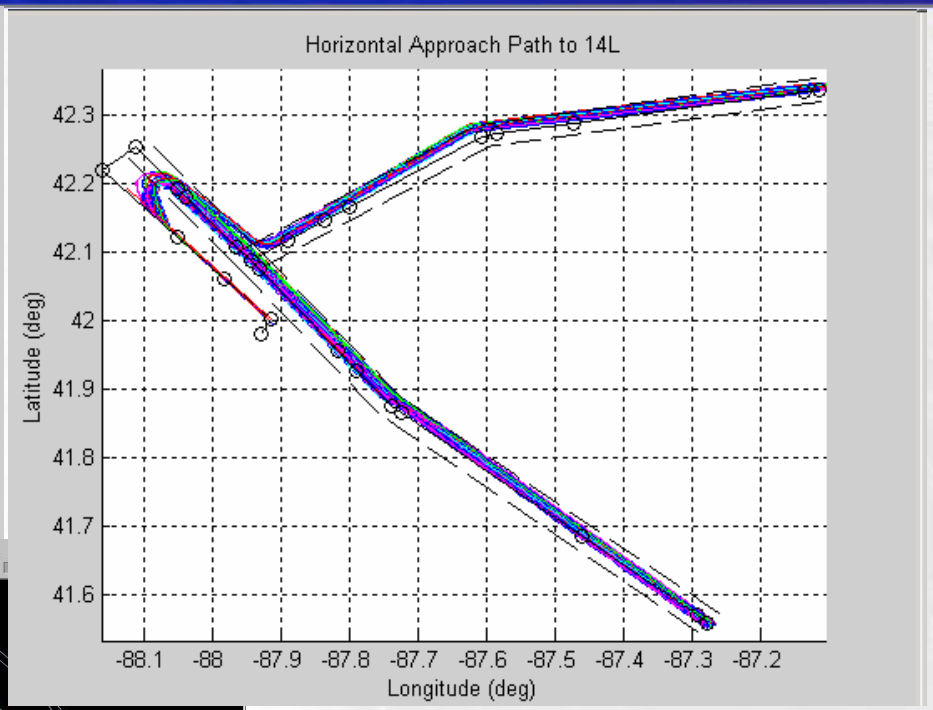
Example top level user interface

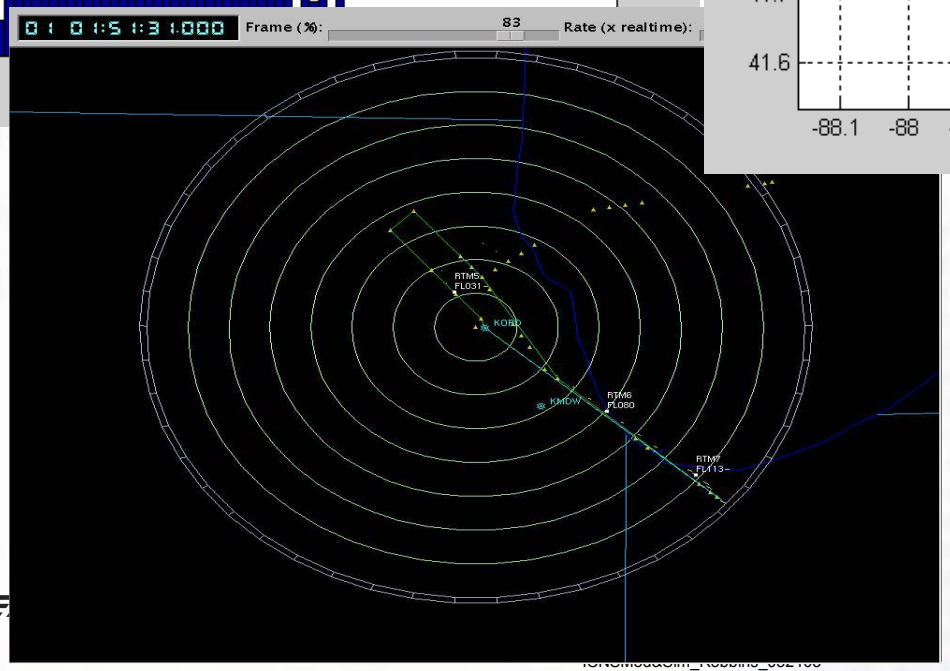


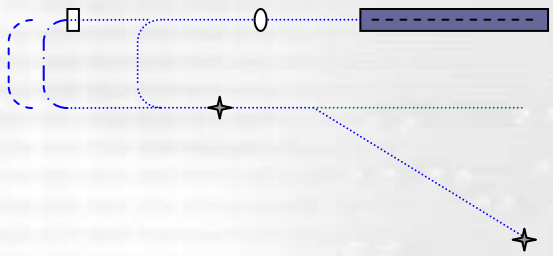


Regional Traffic Model (RTM)









RTM– sample initial analysis (cont'd)

System Parameters

Qualitative Factors	Actual Simulation Variables	DOE Levels		
		-1	0	1
SurveillanceAccuracy	POSvar	74.08	185.2	296.32
	velVar	1.02888	2.5722	4.11552
SurveillanceFrequency	sweep_time	2	5	8
	velocity lag	8	20	32
ConflictPredictionPeriod	timeIntervalForConflictPrediction	3	30	57
HAMtimes	ControllerReactionTimeMean	1	2	3
	ControllerReactionTimeStdDev	0.5	1	1.5
	ControllerReactionTimeLowerBound	0.25	0.5	0.75
	ControllerReactionTimeUpperBound	2.5	5	7.5
	ControllerCognitiveProcessingTime	1.11	2.22	3.33
	PilotreactionTimeMean	1	2	3
	PilotReactionTimeStdDev	0.5	1	1.5
	PilotReactionTimeLowerBound	0.5	1	1.5
	PilotReactionTimeUpperBound	2.5	5	7.5

RTM

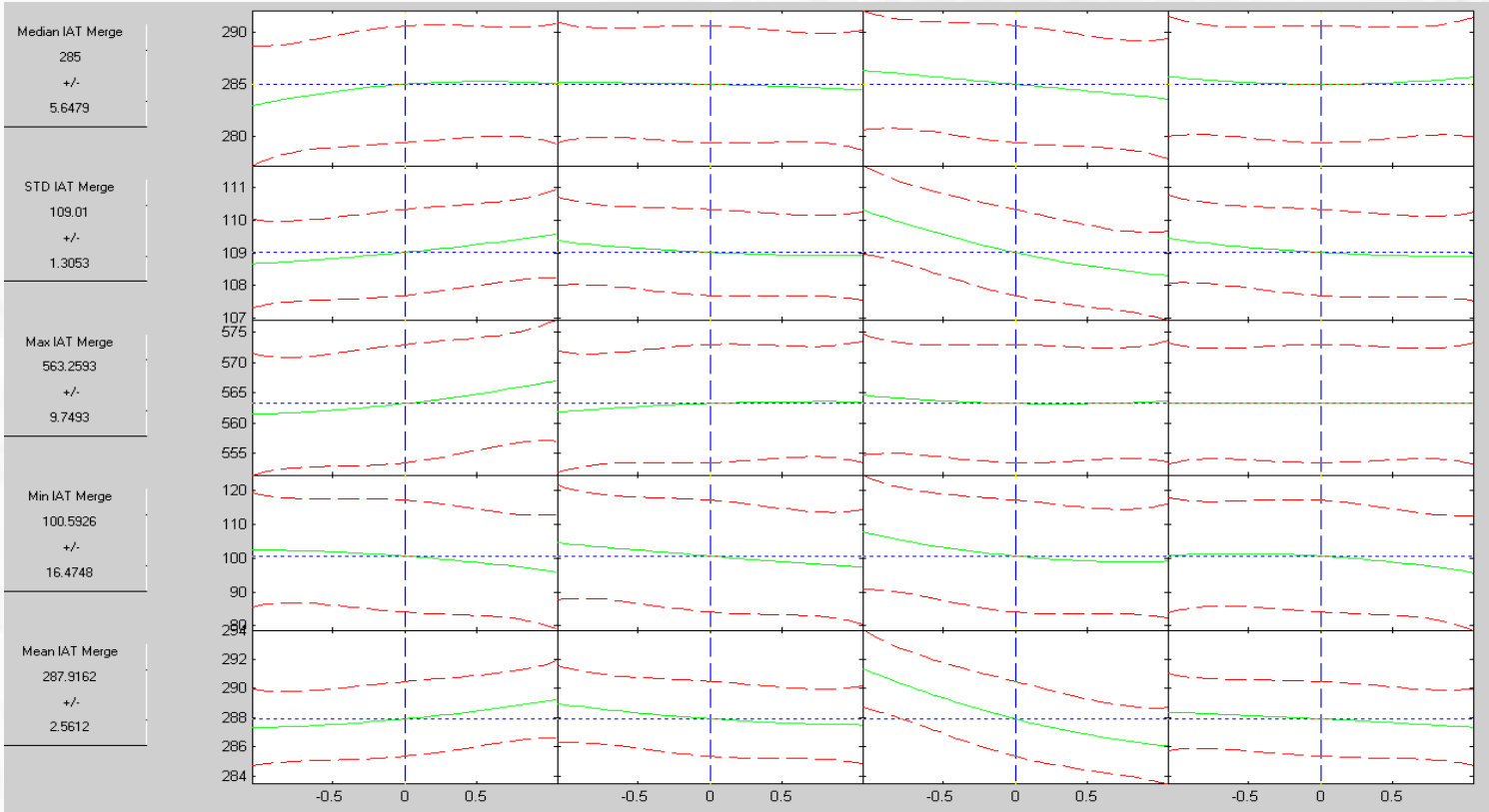
Design of Experiment List of Parameter Combinations: DESERTMAN

Experiment #	SurveillanceAccuracy	SurveillanceFrequency	ConflictPredictionPeriod	HAMtimes
1	-1	-1	-1	-1
2	0	-1	-1	-1
3	1	-1	-1	-1
4	-1	0	-1	-1
5	0	0	-1	-1
6	1	0	-1	-1
7	-1	1	-1	-1
8	0	1	-1	-1
9	1	1	-1	-1
10	-1	-1	0	-1
⋮				
75	1	-1	1	1
76	-1	0	1	1
77	0	0	1	1
78	1	0	1	1
79	-1	1	1	1
80	0	1	1	1
81	1	1	1	1

Metrics

- Mean IAT Merge
- Min IAT Merge
- Max IAT Merge
- Std IAT Merge
- Median IAT Merge
- Mean Inst. Tpt Merge
- Min Inst. Tpt Merge
- Max Inst. Tpt Merge
- Std Inst. Tpt Merge
- Median Inst. Tpt Merge
- Mean IAT Runway
- Min IAT Runway
- Max IAT Runway
- Std IAT Runway
- Median IAT Runway
- Mean Inst. Tpt Runway
- Min Inst. Tpt Runway
- Max Inst. Tpt Runway
- Std Inst. Tpt Runway
- Median Inst. Tpt Runway
- Diversion Rate
- COM Useage
- NPO Ratio
- Good Landing Rate
- Num Alt Violations
- Num Lat Violations
- Num Speed Violations

RTM – sample initial analysis (cont'd)
Parameter sensitivities of metrics



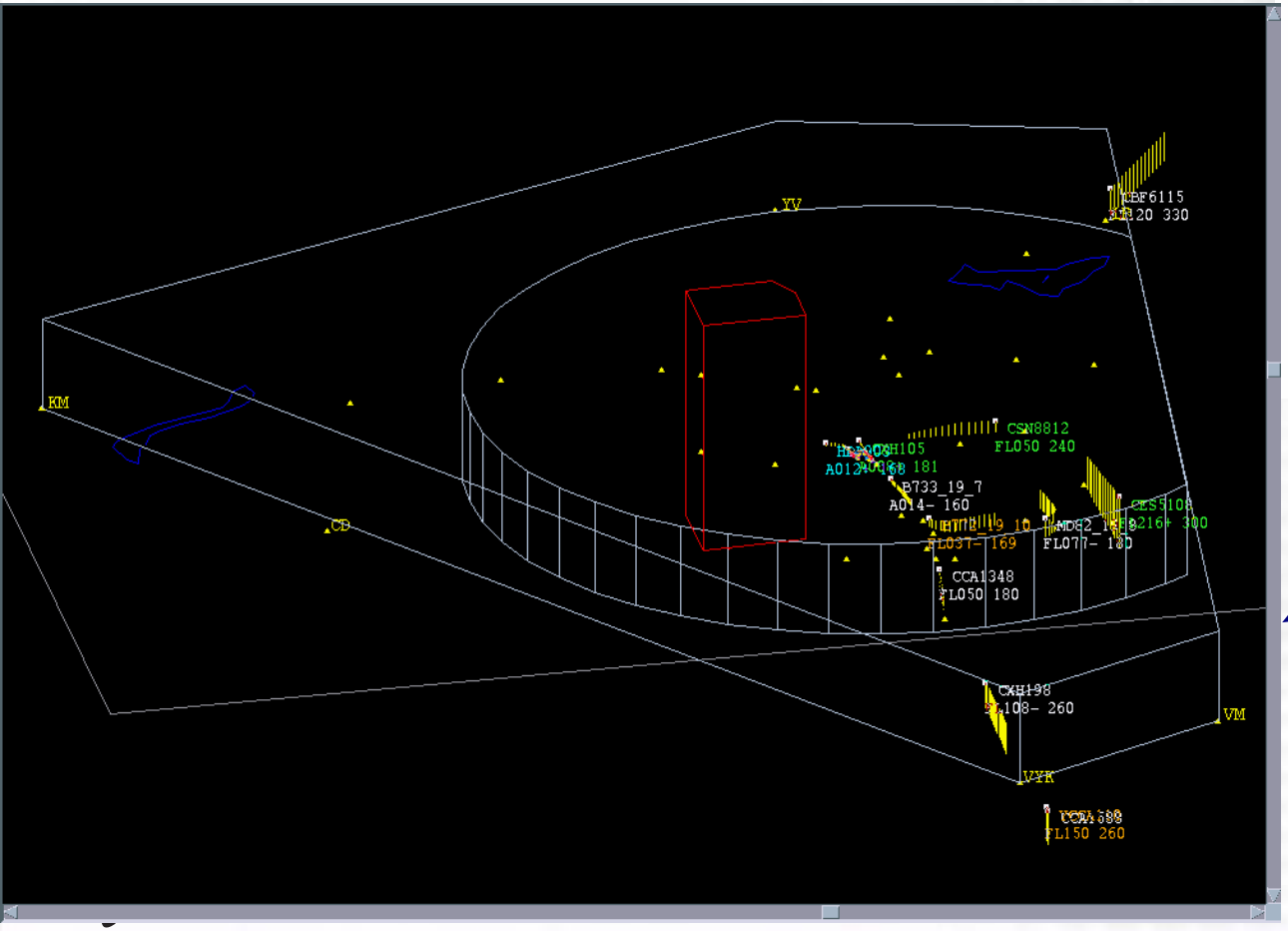
TAAM – Total Airspace & Airport Modeller

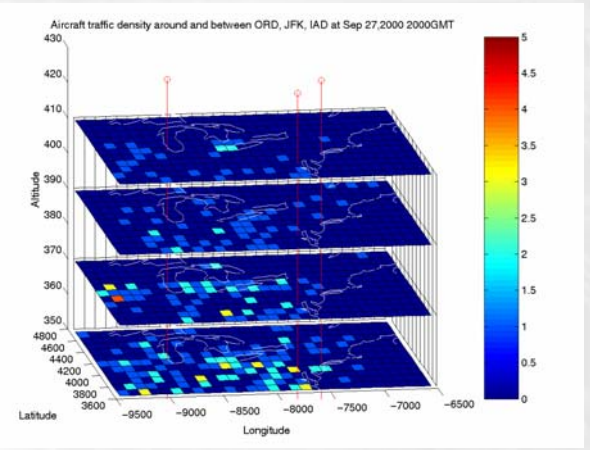
- Developed by Preston Aviation Solutions, a wholly owned subsidiary of The Boeing Company
- SIM is a discrete event simulator
- Not a playback but a design, analysis, what-if tool
- Has ATC model built in
- Fast-time gate-to-gate simulation
- Parameters and rulebase
- Used in ATM modeling projects since 1995
  - ERAM model under Lockheed Martin
  - Ground operations studies: (767-400 at LGA; Beijing and SEA ground operations study)
  - Airspace studies: (Bay of Bengal procedural airspace analysis, Cleveland free-flight conflict probe)
  - Current ATM trade studies and other analyses

Airspace and airport modeling schedule generation process overview

ASDI/AADS Traffic and Schedule Generation
Or
OAG/other source traffic data

Data Filtering and Verification Tools
(UNIX, MATLAB, others)





(Traffic Density Analysis)

TAAM Simulation

Air Traffic Management

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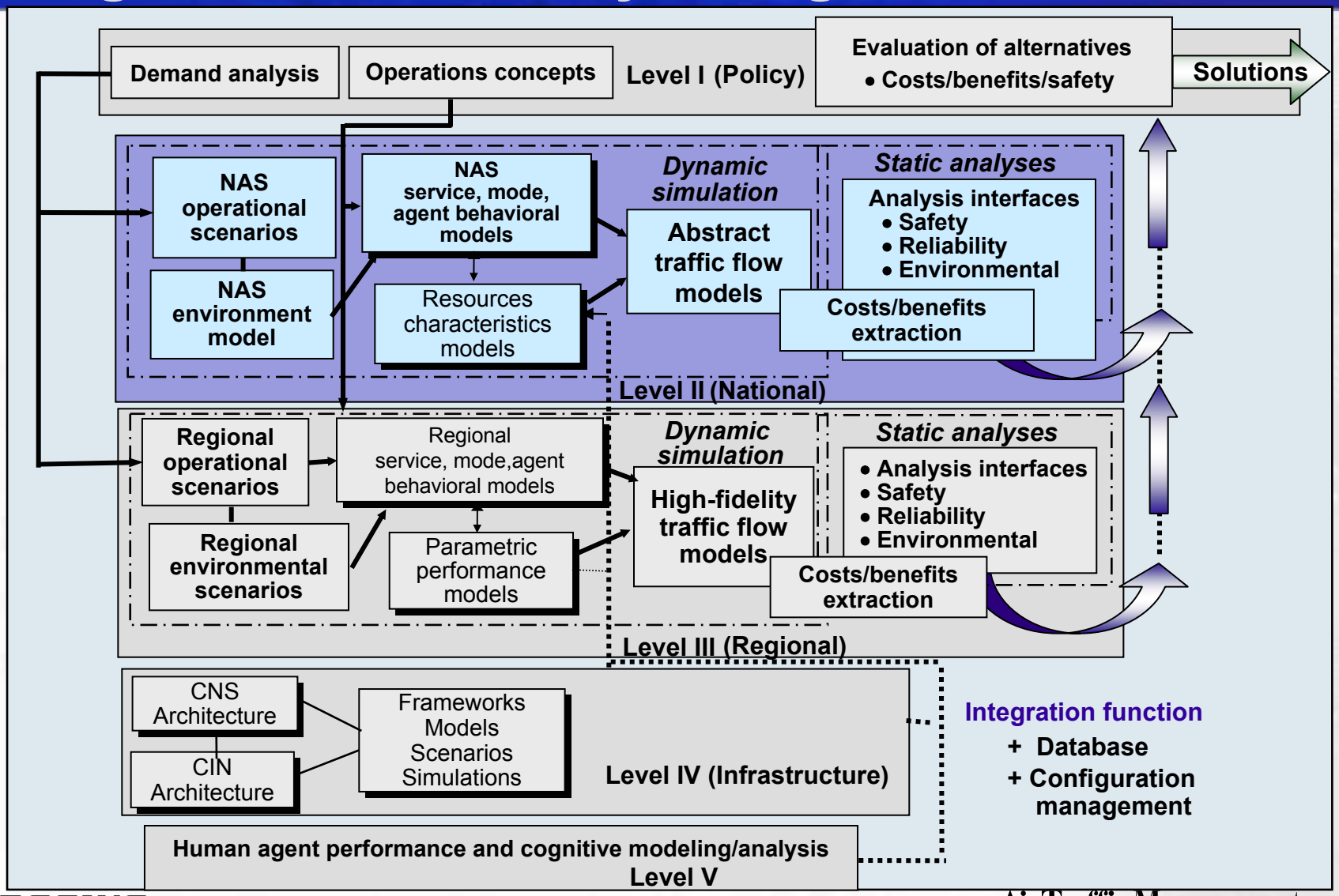
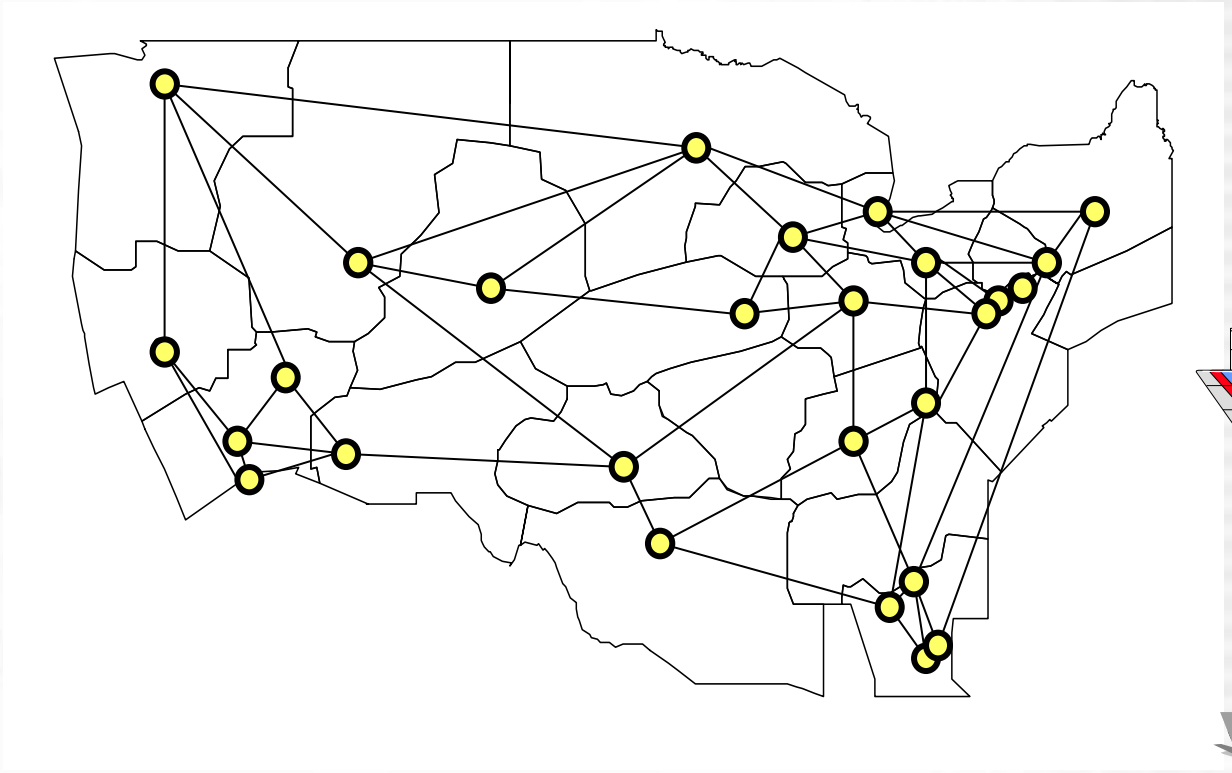


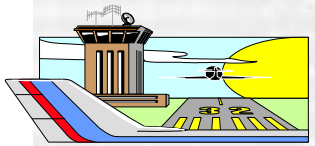
National Flow Model (NFM) resource queuing simulation technique



ETMS /OAG

Traffic represented by ETMS flight plans (FZ) and departure records (DZ) or OAG schedule

Simulation schedules aircraft on queues

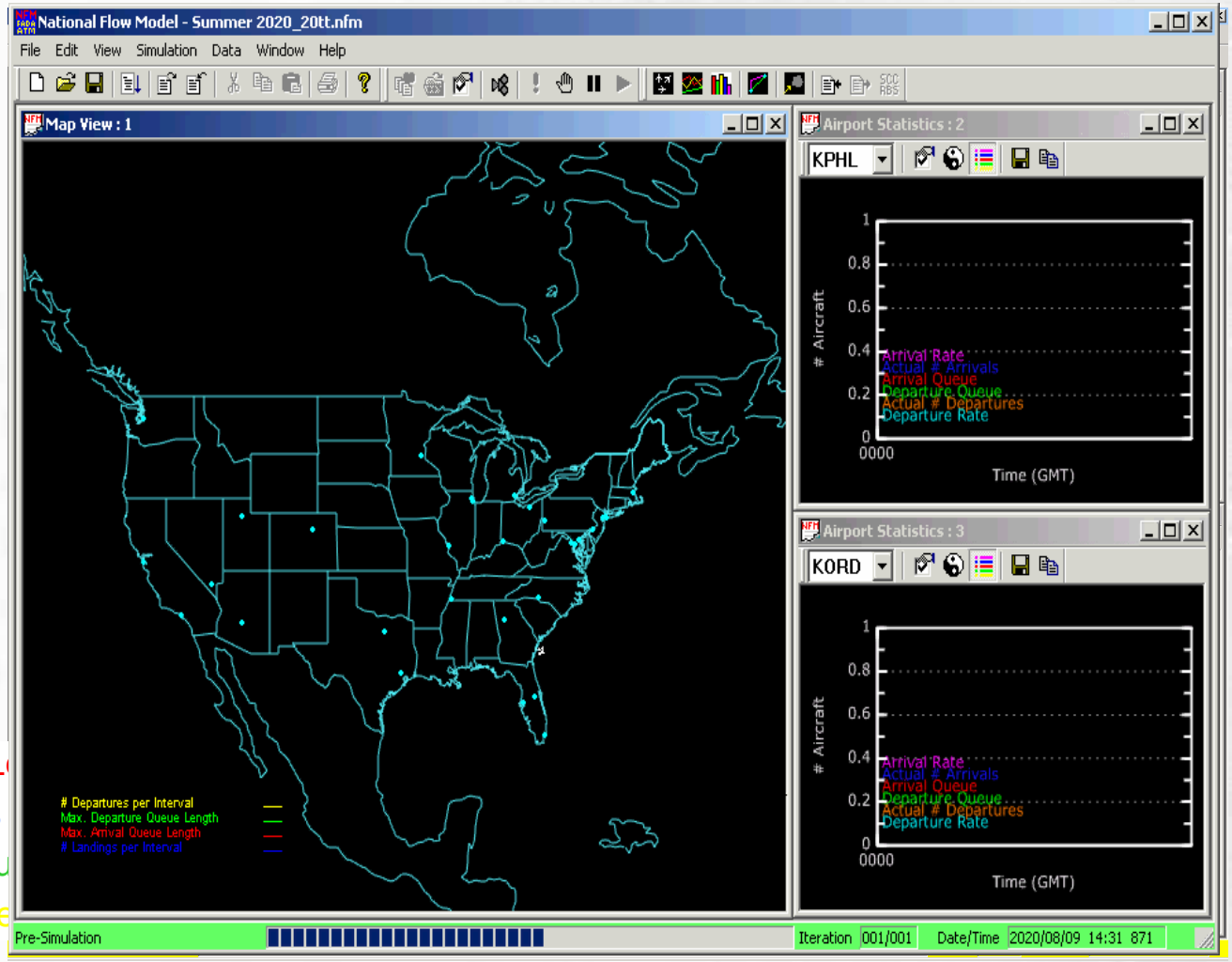


Airports and/or runways … represented as queues

Aircraft enter and leave network segments according to event queue schedule

Aircraft move between queues over the network

NFM demo: Summer 2020



-- Max Arrival Queue L
-- Number of Landings
-- Max Departure Queu
-- Number of Departure

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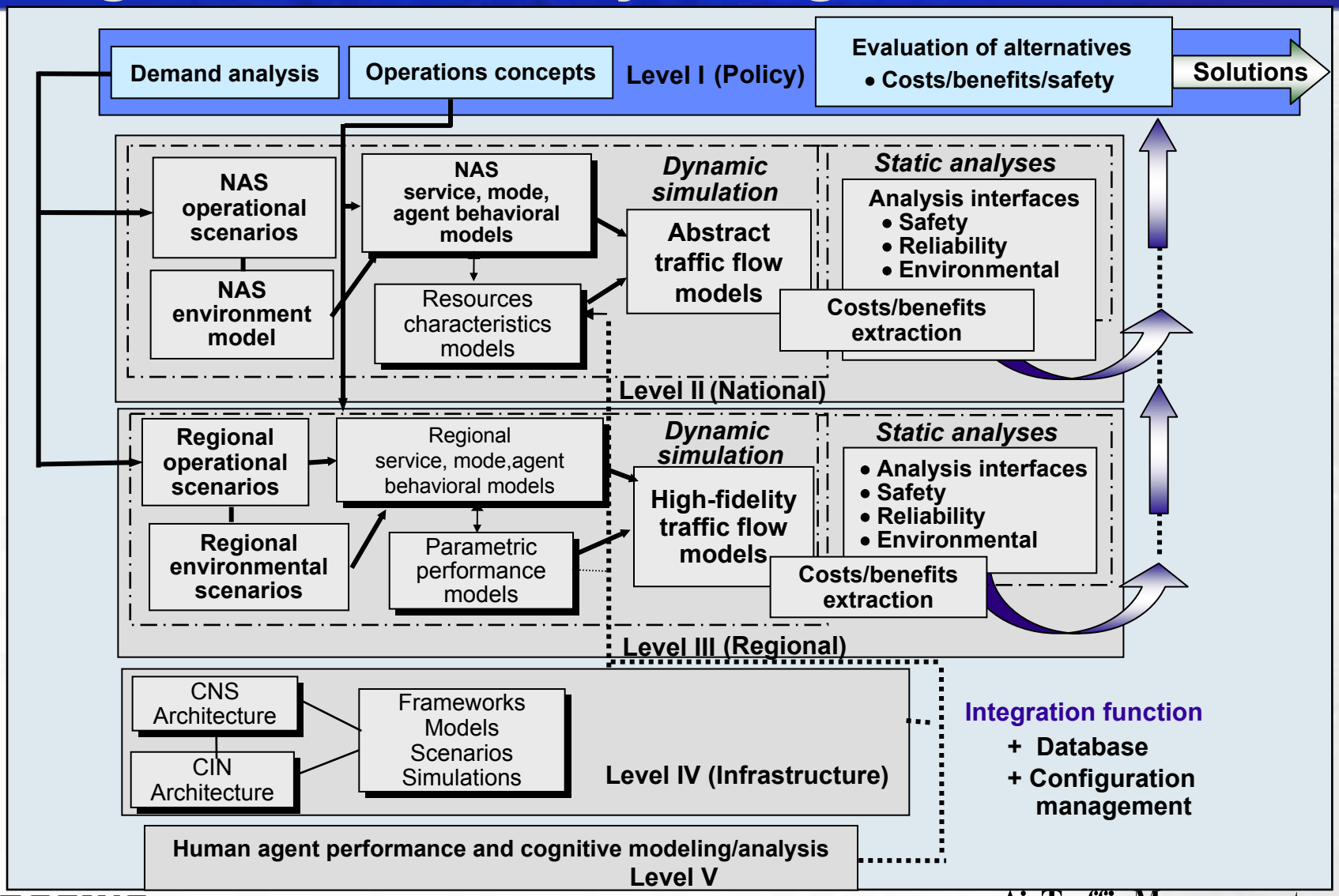
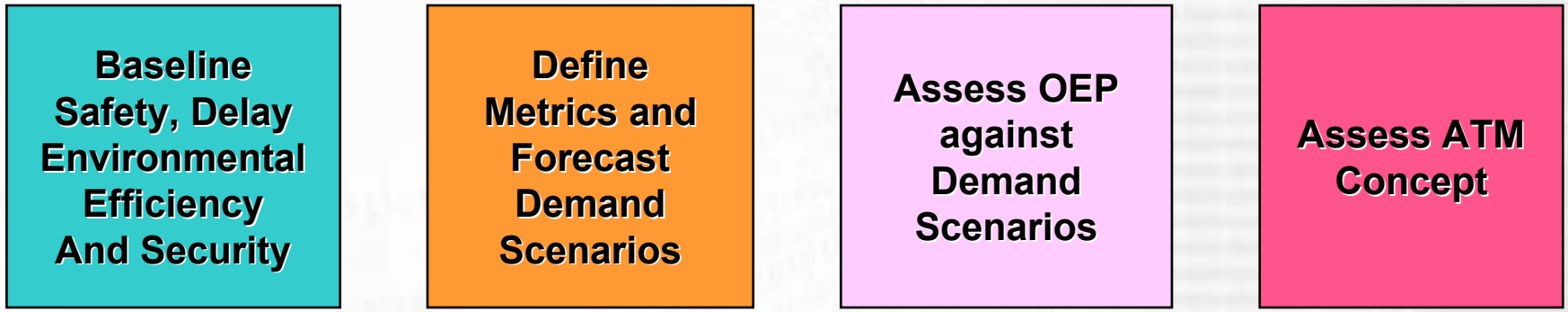


Benefits analysis

- Evaluate the benefits of changes to technology, operational concepts or implementation strategies
- We determined feasibility (can we) and implementation (how do we do it), now we need to determine should we (why)?

Boeing approach

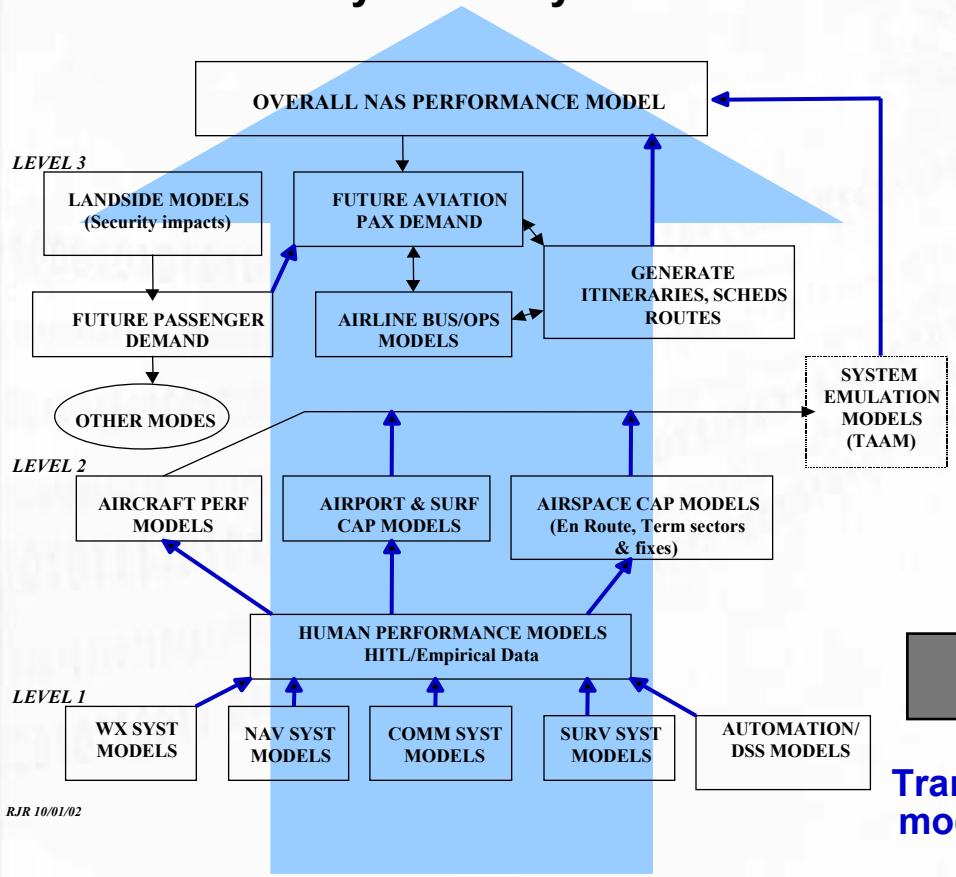


ATM Objectives

- Affordability
- Capacity
- Safety
- Global Interoperability
- Environmental Efficiency
- Security

Fundamental ATM modernization requires a new modeling and simulation approach

Modeling the performance of Today's ATM system

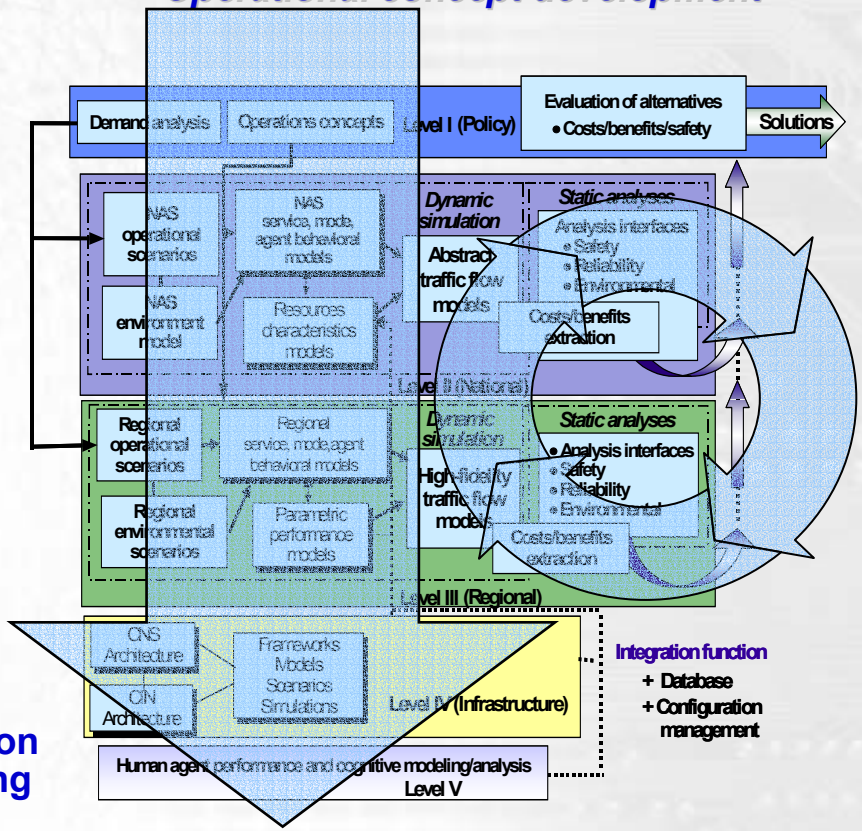


Bottom-Up analysis

Transition modeling

Designing tomorrow's ATM system

Top-Down requirements and Operational concept development



Need to do both

Summary

- A full system modeling and simulation approach is a key enabler for fundamental ATM modernization
- Top-down, requirements-driven (not technology-driven) systems engineering is critical
  - Models and tools are used as enablers – to quantify analysis / concepts feasibility
  - Leverage existing tools, models, scenarios
- Future ATM modeling and simulation must be derived from the same systems engineering approach
  - Start with the operational concept, then derive functional allocations and supporting technologies covering “can we?” as well as “should we?”
- Much has been accomplished; much work remains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Questions
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